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Doris Warren
DOCUMENT CONTROL ADMINISTRATOR

INSTRUCTION MANUAL

MODEL 77A-S4

CAPACITANCE LIMIT BRIDGE

SERIAL NO. _____

Meter & Standards

BOONTON ELECTRONICS CORPORATION

TELEPHONE: 201-887-5110
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ROUTE 287 AT SMITH ROAD
PARSIPPANY, N. J.— 07054

PMB 9/64

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SPECIAL MODEL RECORD

Boonton ELECTRONICS Corp.

MODEL 77A-54 FIRST SERIAL NO. _____

FIRST CUSTOMER Weston Electric MO 10-29-64

_____ MO DATE _____

New Version of 77A

Description of Special Features:

Similar to 77A except.

1. Test Frequency 100 KC
2. Bias supply DC

Method of Marking Special Model No. on Instrument: not reqd.

Price on First Unit _____ Price Change to _____

Additional Serial No. _____

FORM 124

77A CAPACITANCE LIMIT BRIDGE
INSTRUCTION MANUAL

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1.0 SPECIFICATIONS

1.1 CAPACITANCE RANGE OF BRIDGE CIRCUIT:

0.0002 pf to 1000 pf in 4 decade ranges

Multiplier	Capacitance Range	Accuracy*	
1.0	100-1000 pf (0.2 pf/div.)	$\pm$(0.25% + $\frac{1000}{R_p}$ pf + 0.5 pf)	Direct
0.1	10-100 pf (0.02 pf/div.)	$\pm$(0.25% + $\frac{1000}{R_p}$ pf + 0.02 pf)	Direct
0.01	1-10 pf (0.002 pf/div.)	$\pm$(0.25% + $\frac{1000}{R_p}$ pf + 0.005 pf)	Direct
0.001	0.05-1 pf 0-0.05 pf (0.0002 pf/div.)	$\pm$(0.25% + $\frac{1000}{R_p}$ pf + 0.001 pf)	Direct

*Where R_p is the equivalent parallel resistance of the test in ohms.

1.2 CONDUCTANCE: 0.01 to 1000 micromhos in 4 decade ranges

Divider	Conductance Range	Accuracy*
1	100 to 1000 µmhos	$\pm(10\% + \frac{Q}{500}\% + 10.0$ µmhos)
10	10 to 100 µmhos	$\pm(10\% + \frac{Q}{500}\% + 1.0$ µmho)
100	1 to 10 µmhos	$\pm(10\% + \frac{Q}{500}\% + 0.1$ µmho)
1000	0 to 1 µmho	$\pm(10\% + \frac{Q}{500}\% + 0.01$ µmho)

1.3 RESISTANCE: 1000Ω to 100 megohms in 4 decade ranges

Multiplier	Resistance Range Δ	Accuracy*
1	1K to 10K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^3}\%)$
10	10K to 100K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^4}\%)$
100	100K to 1 megohm	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^5}\%)$
1000	1 megohm to ∞	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^6}\%)$

Δ Where R is the measured resistance in ohms.

*These specifications apply to tests made directly at the HI and LO TEST coaxial receptacles. See Section 6 "Measuring Techniques" for limitations applicable to remote measurements.

1.4 GENERAL

1.4.1 TEST SIGNAL

Self-contained oscillator/detector; fixed, 1 Mc ±10 Kc; level continously adjustable from 200 mv to 1 mv.

1.4.2 DC BIAS

Internally supplied; continuously adjustable from +100 v to -7 v. Externally provided bias up to ±400 v @ 100 ma, ac or dc.

1.4.3 LIMIT FUNCTION

1.4.3.1 Test Time - Approximately 0.1 sec.

1.4.3.2 Limit Resolution - 0.001 pf

1.4.3.3 Decision Outputs - Visual: Front panel indicator lamps, red for High, green for Low.

Electrical: Sample of filament voltage to indicator lamps, 6.3 v, approx. 0.5 a, 60 cps at rear connector.

Continuity: Relay contacts accessible at rear connector; rating, 250 v, 125 ma, or up to 4 watts/volt amperes, resistive.

1.4.4 TUBE COMPLEMENT

1 ea. 6C4, 6X4, OA2
2 ea. 12AT7 (matched pair)
4 ea. 6AU6

1.4.5 PRIMARY POWER

105-125 v, 50-60 cps, 50 w

1.4.6 PHYSICAL CHARACTERISTICS

Dimensions: 11-1/4" h x 19-1/2" w x 12-3/4" d, overall, in cabinet; 10-1/2"h x 19" w x 10-1/8" behind panel when rack mounted.
Weight: In cabinet: 35 lbs net;
In rack, 25 lbs.

2.0 GENERAL DESCRIPTION

2.1 APPLICATION

The Model 77A is a precise, sensitive, highly stable capacitance bridge designed primarily for automatic, high-speed, capacitance-limit tests at one megacycle. In addition to go/no-go testing, the Model 77A may also be used for conventional capacitance measurements.

This instrument embodies a number of features that contribute to its accuracy, convenience and versatility. For example, the Model 77A is completely self-contained, including bridge circuitry, one-megacycle oscillator and dectestor, dc bias supply, limit circuitry, decision outputs, and power supplies. Test signal of the Model 77A is continuously adjustable from 200 mv down to 1 mv, permitting a variety of specialized tests, especially on semiconductor devices.

Internally supplied dc bias (standard on all Model 77A's) is continuously adjustable from +100 v to -7 v, and is particularly valuable for tests on varactors and similar voltage sensitive components. Externally provided bias may be applied up to $\pm$400 v @ 100 ma, ac or dc. In addition to the visual (indicator lamp) decision outputs, both electrical and continuity outputs are provided for actuation of associated equipment.

All dials of the Model 77A are direct reading, and operation of the instrument is convenient and straightforward.

As a capacitance bridge, the Model 77A offers high resolution over a wide measuring range, and the instrument's ability to operate in the limit mode in no way detracts from its value as a standard capacitance bridge.

2.2 TYPE OF MEASUREMENT

2.2.1 GENERAL

2.2.1.1 Direct-capacitance measurements can be made to a higher degree of accuracy than GROUNDED measurements. particularly when the test capacitance is small (less than 100 pf) and when long test leads are necessary. Use of the DIRECT method also reduces hand capacitance effects as well as the test capacitor position error.

2.2.1.2 When direct-capacitance measurements are made at the terminals of the coaxial cables, test accuracy is not affected by the cables being bent, twisted, moved, or subjected to wide temperature variations.

2.2.1.3 Much of the accuracy of capacitance measurements depends on the technique of connecting the test capacitor to the bridge; e.g., when measuring the grounded-capacitance of a 10 pf mica capacitor, the variation due to connection technique may be as much as 1 pf.

2.2.2 DIRECT-CAPACITANCE MEASUREMENTS

2.2.2.1 Whether measurements are being made at the TEST posts or at the terminals of remote cables connected to the REMOTE TEST coaxial jacks, the test capacitor should be connected with leads as short as possible.

2.2.2.2 If feasible, connect the test capacitor directly by inserting the wire leads into the center conductor of the HI and LO coaxial TEST jacks. This technique has the advantage that the outer shell of each jack shields the leads from each other for part of their length.

2.2.2.3 For maximum accuracy use a test fixture to keep the capacitance between the leads of the test capacitor from influencing the measurement.

2.2.2.4 All other conductors in the immediate vicinity of the elements under test must be connected to ground.

2.2.3 EXAMPLES

2.2.3.1 Direct-capacitance is the capacitance existing between two conducting elements EXCLUDING all stray capacitance that may exist to other conducting elements. Typical examples of direct-capacitance measurements are:

2.2.3.2 Capacitance measurement between the control grid and the plate of a pentode vacuum tube, excluding the capacitance to the cathode, screen grid, or suppressor grid.

2.2.3.3 Capacitance measurement between any two conductors in a cable, excluding the capacitance to all other conductors or to the shield.

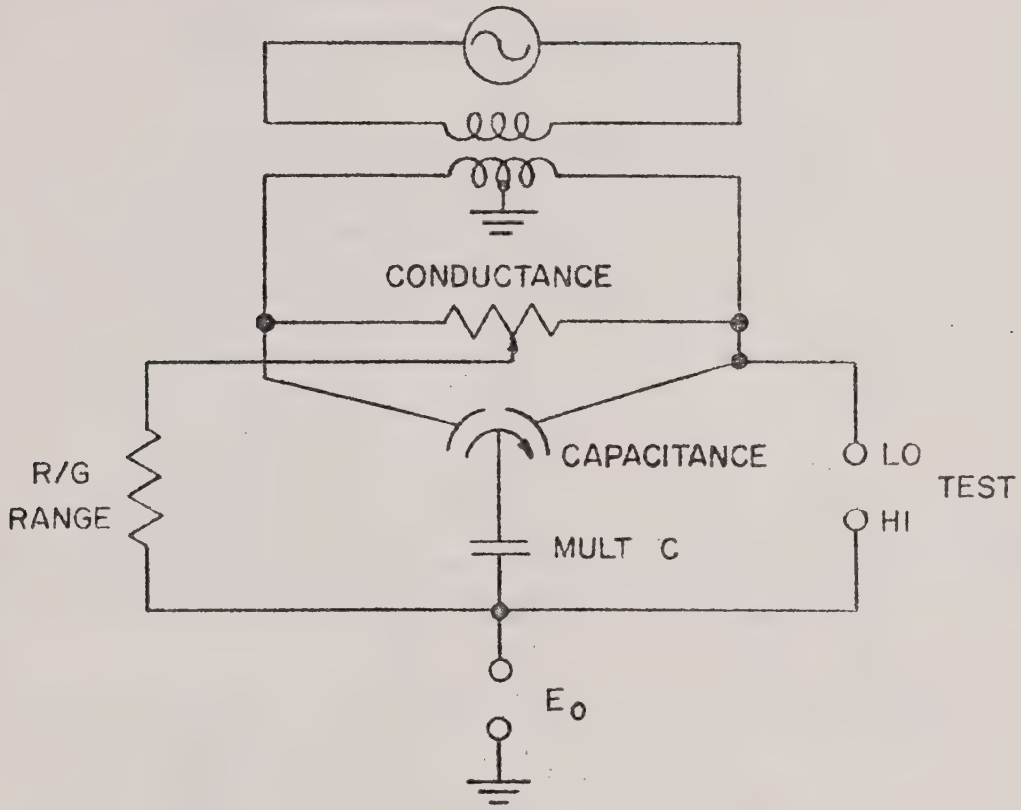
2.2.3.4 Capacitance measurement between any two conductors of a printed circuit, excluding capacitance to all other conductors.

2.2.3.5 Capacitance measurement between any two windings of a transformer, excluding capacitance to all other windings or shields.

2.2.3.6 Capacitance measurement of semiconductors such as diodes or voltage sensitive capacitive devices.

3.0 CIRCUIT DESCRIPTION

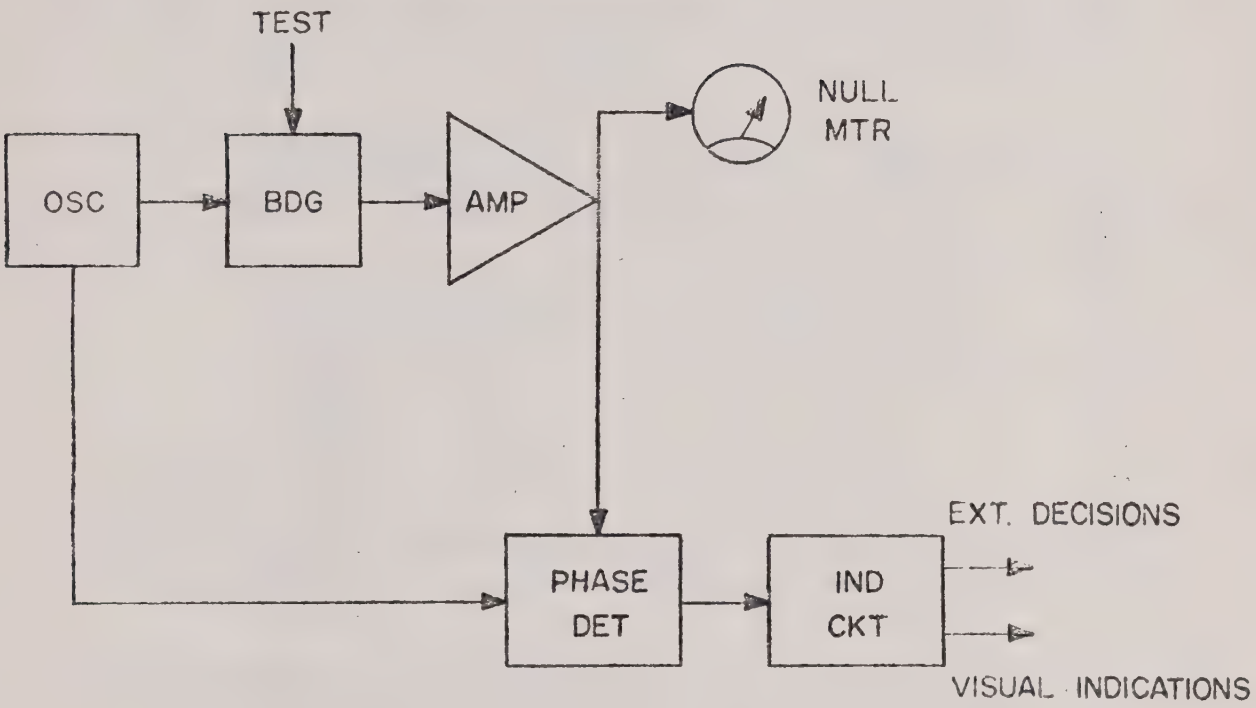
3.1 BASIC BRIDGE CIRCUIT



3.1.1 The method of measurement is of the "Differential" mode. A capacitance specimen is placed at the test terminals causing an unbalance in the TEST side of the bridge which then must be corrected by removing a similar capacitance from the internal STANDARD arm. Conductance is similarly balanced.

3.1.2 When the bridge is in an unbalance state an error voltage appears across its output. This error voltage will reach a minimum when the conductance and capacitance specimen are balanced.

3.2 INSTRUMENT FUNCTION



3.2.1 A unique Phase Sensitive Detector circuit is incorporated in conjunction with the null meter circuit to provide instant capacitance value determination.

3.2.2 Two r-f signals are applied to the phase detector. One signal comes from the oscillator and the other being an error signal generated from the bridge. The two signals are compared and their phase relation establishes which visual indicator lamp shall glow. The phase of the error signal depends upon capacity and not on conductance and therefore loss factors have negligible affect on capacitance accuracy.

3.2.3 In sequence with the indicator lamps are Decision Outputs for external use. (See paragraph 4.4)

4.0 OPERATING PROCEDURE

4.1 SET-UP AND ZERO BALANCING

4.1.1 Connect bridge to appropriate power source and set power switch to ON position. Allow instrument to warm up for approximately one hour.

4.1.2 Set the conductance range selector switch marked DIVIDE G/MULTIPLY R to 10 and the MULTIPLY C switch to the position indicated below:

Range of Capacitance To Be Measured	Setting of MULT. C. Sw.
1000 - 100 pf	1
100 - 10 pf	0.1
10 - 1 pf	0.01
1 - 0 pf	0.001

4.1.3 Set the CONDUCTANCE dial to zero and the CAPACITANCE dial to zero. (Both vernier and counter dials should read zero.)

4.1.4 Connect test leads or fixtures as detailed in Section 5 "Measuring Techniques" if required.

4.1.5 If the test signal must be set at a definite level, connect a suitable a-c VTVM (BEC 91CA or equivalent) to the LO TEST receptacle and use the TEST level control to obtain the desired value. (The normal range of adjustment is approximately 200 millivolts maximum to 1 millivolt minimum.)

4.1.6 Adjust zero balance controls, located to the right of the main CAPACITANCE and CONDUCTANCE dials, until the NULL INDICATOR meter reads nearly zero and both indicator lamps flicker.

4.1.7 Move the CAPACITANCE dial to the left and then to the right of the fiducial line. The green and red indicating lights should illuminate alternately.

4.1.8 Return the CAPACITANCE dial to zero and then set CONDUCTANCE dial to last red graduation to the left of zero.

4.1.9 Adjust the "Phase Adjust" control until both limit lights are on, or both out, or flicker alternately. Repeat steps 4.1.6 through 4.1.9.

4.1.10 Return CONDUCTANCE dial to zero null.

4.2 MEASURING

4.2.1 Complete connections to the TEST TERMINALS utilizing appropriate techniques as described in section 5.

4.2.2 Set capacitance dial to desired value and connect specimen. Observe indicator lamps to determine if capacitance is above or below desired value. Red lamp glowing indicates specimen is above dial setting; green lamp glowing indicates specimen is below dial setting.

4.2.3 When it is desired to determine the exact value, connect specimen and rotate capacitance dial above zero to the point where the indicator lamps just change state; this is the specimen capacitance.

4.3 SEMICONDUCTOR MEASUREMENTS

4.3.1 When measuring semiconductors both test level and bias affects capacitance and conductance.

4.3.2 When measuring diodes it is desirable to reduce the TEST LEVEL to a point where the "Turn Over" effect is negligible with OVDC bias. That is, when switching the position of the diode with respect to the Hi and Lo terminals of the instrument, there is minimum capacitance or conductance change.

4.4 DECISION OUTPUTS

4.4.1 GENERAL

4.4.1.1 Voltage and continuity outputs of the test decision are available at a 6-pin connector located at the rear of the instrument's chassis. A mating 6-pin plug is supplied as a standard accessory with the Model 77A.

4.4.1.2 Voltage Ouputs are 6.3 VAC filament voltage to each indicator lamp, and provides a 60 ∿ ac signal approximately 0.5 amp to actuate external equipment.

4.4.1.3 Each of the two test result indicator lamps is controlled by a double-pole relay. One pole of which operates the lamp and the other is brought out to the 6-pin connector to provide a continuity output of the test decision for switching external equipment.

4.4.2 RATINGS

4.4.2.1 Typical load ability of the reed relay contacts is 250 V at 125 ma or up to 4 watts/volt amps. Exceeding this rating shall cause permanent damage to the contacts. (For inductive switching, adequate protection should be provided.)

4.5 BIAS

4.5.1 Application

4.5.1.1 The 77A Capacitance Limit Bridge has provisions for applying either an internal D.C. or an external voltage to the test specimen. This greatly enhances the use of the instrument due to its ability to measure small capacitance changes with voltage. As for example: diodes, varactors, voltage varying capacitance diodes, transistors, or any non-linear device.

4.5.2 Operation

4.5.2.1 In either + INT or - INT bias switch position a +100 VDC or -7 VDC internal voltage is available respectively; and is continuously adjustable at the front panel.

Monitoring current at a current jack and voltage at insulated terminal posts is provided.

4.5.2.2 In the EXT bias switch position an external voltage may be applied up to 400 V @ 100 ma. This voltage is not controlled at the front panel but may be monitored at the insulated terminal posts.

5.0 MEASURING TECHNIQUES

5.1 GENERAL

5.1.1 When using a test frequency of 1 Mc, the effect of added lead length between the bridge and the test specimen cannot always be neglected. With large capacitance tests, the resulting error is primarily due to the lead inductance and resistance.

5.1.2 For capacitance values above about 50 pf, increased lead length produces higher readings of both capacitance and conductance. Each foot of extension of the two leads increases the readings approximately as given:

Capacitance to be measured	Approx. increase in reading for 1 ft. of RG-58/U cables. C	G
1000 pf	+ 7 pf	+ 4 µmhos
750 pf	+ 4 pf	+ 2 µmhos
500 pf	+ 1.9 pf	+ 1 µmho
300 pf	+ 0.8 pf	+ 0.4 µmho
100 pf	+ 0.1 pf	+ 0.05 µmho

5.1.3 Below 50 pf the error due to lead inductance becomes less important than that caused by the effects of stray capacitances in the test or connecting cables. If the test is a pure two terminal capacitor (without shunt capacitances from either terminal to ground) the error introduced by measuring on coaxial cables is small (see Graph 1 "Measurement Error Due to Cable Inductance").

5.1.4 When the test has appreciable capacitance between one of its terminals and ground, that terminal should be connected to the LO TEST receptacle on the bridge. This greatly minimizes errors when measuring fractional pf capacitors.

5.1.5 The errors resulting from measuring a test having appreciable stray capacitance between both its terminals and ground can become significant.

5.1.6 Whenever feasible, the Direct method of measurement should be used because it greatly reduces hand capacitance effects as well as the test specimen position error which are basic limitations when making grounded measurements.

5.1.7 Contact fixtures may be used for production testing provided their residual direct capacitance does not exceed the range of the C Zero control (approx. 10 pf).

5.2 DIRECT CAPACITANCE MEASUREMENTS AT TEST TERMINALS

5.2.1 If measurements are to be made at the HI & LO TEST binding posts, the test specimen should be connected as close as possible to these posts. All other conductors in the immediate vicinity of the elements under test must be connected to ground using the GND binding post on the front panel.

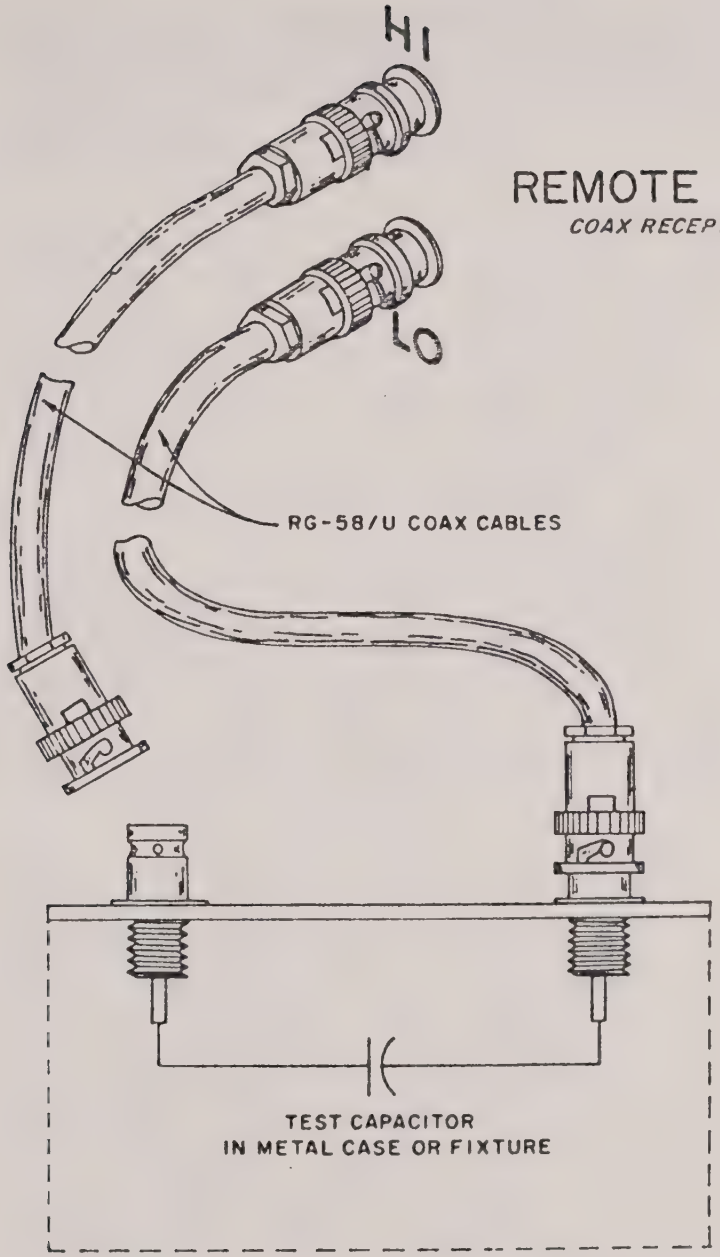
5.2.2 In many cases it may be more convenient to insert the wire leads of the test specimen directly into the center conductor receptacle of the HI & LO coaxial TEST jacks. This is particularly useful with smaller mica, ceramic or voltage variable types of capacitors and has the advantage that the outer shell of each jack shields the leads from each other for much of their length.

5.3 DIRECT CAPACITANCE REMOTE MEASUREMENTS

5.3.1 Fixture or Jig: If a fixture or jig is to be used. Connect both coaxial leads between it and the bridge before zero balancing. (As with the BEC TF-1 diode jig.)

5.3.2 Shielded Test Equipped with Coaxial Receptacles: When the test is in a metal shield can equipped with coaxial receptacles for connection (as in the BEC CS-10 Direct Capacitance Standard), connect both coaxial cables to the bridge and the LO one to the test before zero balancing.

5.3.3 Open Test Without Shield or Fixture: Connect both Coaxial cables to the bridge, strap or solder their braids together at the test end, and connect the LO center conductor to the test before zero balancing. (The center conductor of the HI cable should be kept away from the test).



SETUP FOR REMOTE MEASUREMENT OF CAPACITORS USING COAXIAL CABLES (DIRECT ONLY)

PROCEDURE:

1. *Connect both cables to the bridge, and connect the* LO *cable to the case receptacle of the test that has the greatest capacitance to case (if any).*

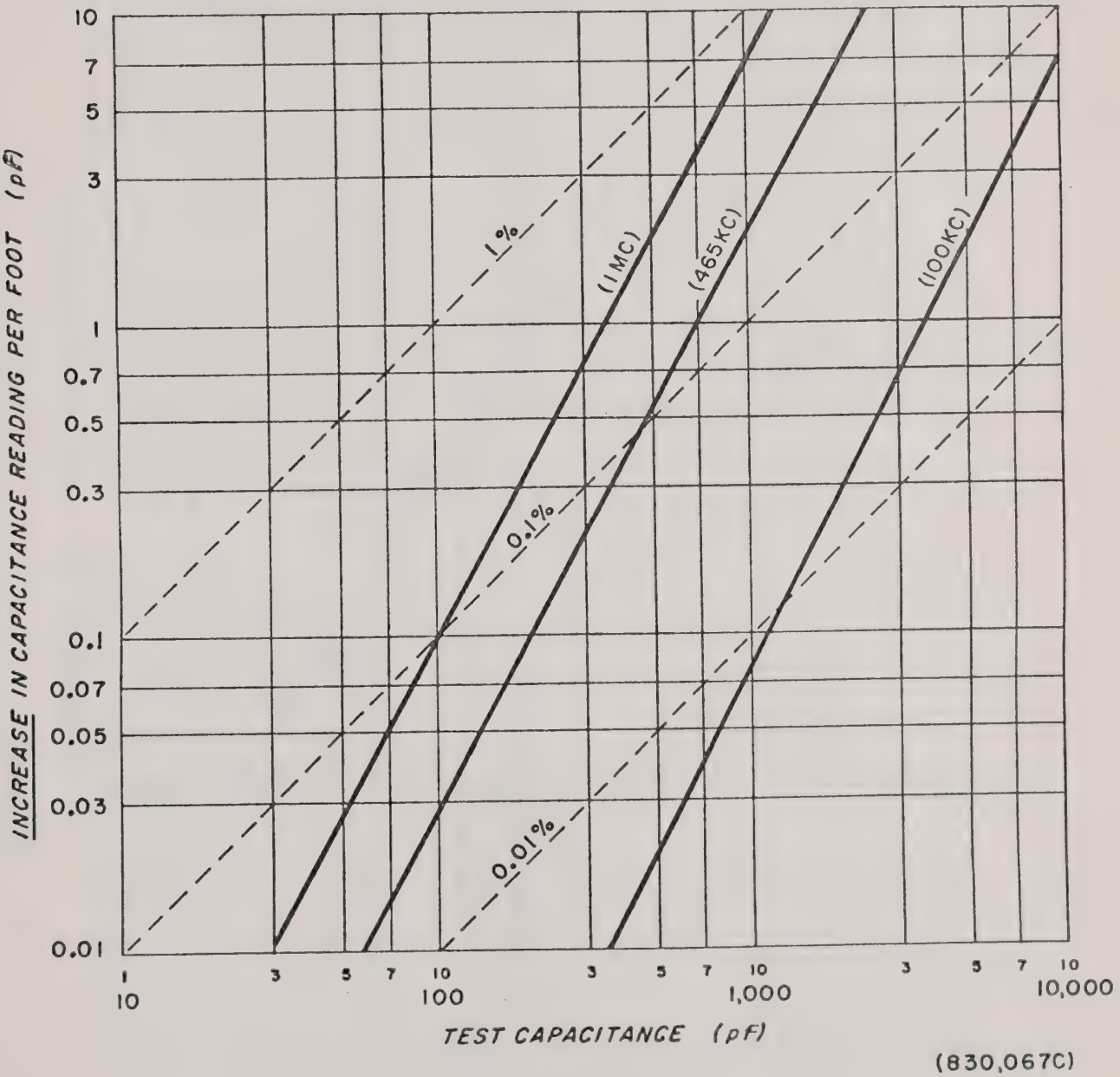
2. *Balance the bridge*

3 *Connect the* HI *cable to the other case receptacle and measure.*

Figure A (830,070A)

REMOTE MEASUREMENT ERROR DUE TO CABLE INDUCTANCE

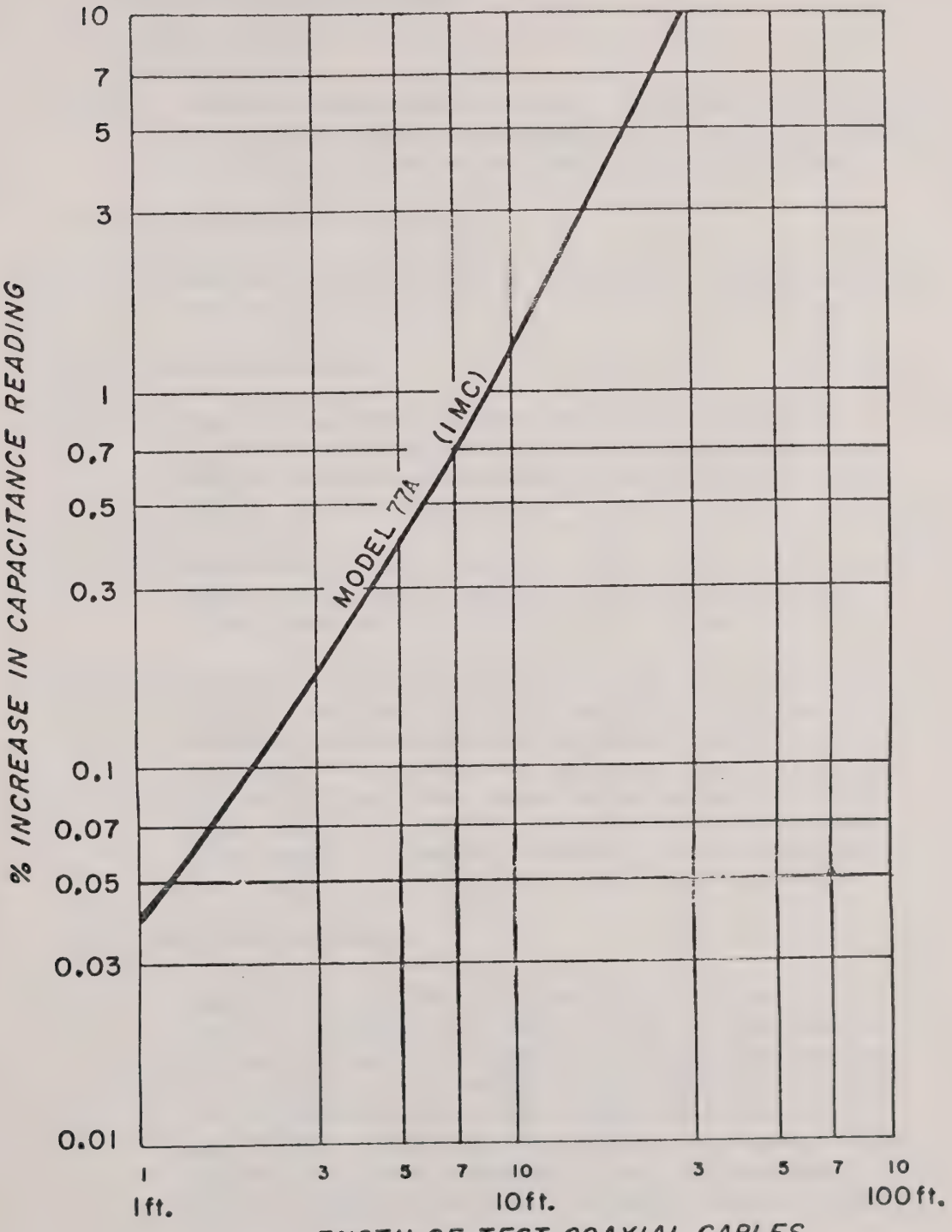
(INCREASE IN CAPACITANCE READING PER FOOT OF RG-58/U CABLES)



Graph 1

77A
8-360

REMOTE MEASUREMENT ERROR DUE TO CABLE CAPACITANCE



Graph 2 (830,068A)

77A
8-360

5.4 REMOTE MEASUREMENT ERRORS

5.4.1 CONNECTIONS

5.4.1.1 Connect both cables to the bridge and connect the LO cable to the case receptacle of the test that has the greatest capacitance to case (if any).

5.4.1.2 Balance the bridge.

5.4.1.3 Connect the HI cable to the other case receptacle and measure.

5.4.2 LEAD INDUCTANCE

5.4.2.1 Above approximately 100 pf the use of 100 KC as the test frequency greatly reduces the error due to the inductance of leads connecting the bridge to the test.

5.4.2.2 Graph #1 shows the added error due to lead inductance when 1 foot long RG-58/U coaxial cables added between the bridge and the test capacitor.

5.4.2.3 It should be noted that Graph #1 does NOT give total measurement errors--only the increase in reading per foot of the specified coaxial cables. At 1 MC, the inductance of leads internal to the bridge can and does contribute appreciable error. This error, of course, is present whether open wire leads or coaxial cable are used to connect the test to the bridge.

5.4.3 CABLE CAPACITANCE

5.4.3.1 Below about 50 pf the capacitance between the center conductor and outer braid of the coaxial cables causes an increase in capacitance reading. This effect is generally negligible at 100 KC, but appreciable at 1 MC. Graph #2 shows the approximate magnitude of this error. Note that the error is not a constant percent-per-foot error; instead, the error becomes greater with longer cable length.

5.5 DIFFERENTIAL MEASUREMENTS

5.5.1 GENERAL

5.5.1.1 In addition to the TEST connections on the front panel, BNC receptacles marked STANDARD ARM have been provided for access to the arm of the bridge opposite that to which a test specimen is connected.

5.5.1.2 For either differential or temperature coefficient measurements the reference capacitor is connected to the STANDARD ARM via the BNC receptacles, and the test specimen to the TEST BNC receptacles. It is desirable to keep the connecting coaxial cables as short as convenient and of equal lengths to both capacitors.

5.5.1.3 If the reference capacitor is adjusted at the start of the test to equal the one being tested, the bridge can then be set to a capacitance range that will give the desired resolution. For example, if a 100 pf ceramic capacitor with a negative T.C. of 300 PPM/°C is to be tested to verify its T.C., a set up can be made with an adjustable air trimmer connected to the STANDARD ARM cables, and the ceramic capacitor connected to the TEST cables. The ceramic capacitor may be in a temperature chamber while the air trimmer is kept at a fixed temperature.

5.5.1.4 The capacitance of the air trimmer can now be set to equal that of the ceramic, and the bridge switched to the X.01 or X.001 capacitance ranges depending on the desired range of capacitance change to be observed. If the X.001 range is selected and the T.C. is nominal, the 30°C change of capacitor temperature should result in a 1 pf capacitance change (full scale deflection). Had the X.01 range been selected, coverage would have been 1/10 of full scale.

5.5.1.5 With the connections previously described, the bridge reading will be direct sensing; that is, an upscale reading indicates an increase of capacitance of the test specimen.

5.5.1.6 When testing capacitors of 10 pf or less for T.C., an external capacitor on the STANDARD ARM is unnecessary since the C ZERO control can be used for that purpose.

5.5.1.7 It is best to leave the power on continuously when the greatest possible stability is required for critical T.C. measurements.

5.5.2 MEASURING

5.5.2.1 For critical differential measurements when the desired information is the exact difference between an unknown and a reference or standard capacitor, the following measuring technique is suggested.

5.5.2.2 Connect the reference to the STANDARD ARM receptacles and the test to the TEST receptacles (using equal length coaxial cables). Follow the general procedure given in SECTION 5 "OPERATING PROCEDURE, SET UP AND ZERO BALANCING", except that the MULTIPLY C and DIVIDE G/MULTIPLY R ranges should be selected to best cover the differences to be measured. It may be helpful to balance with the main CAPACITANCE dial at mid-scale or some point other than zero, so that either increase or decrease of capacitance can be measured on-scale. The C ZERO control has an upscale control range of about 10 pf, thus allowing full scale shift of zero balance on the X.001 MULTIPLY C range, and full or nearly full scale on the X.01 range.

5.5.2.3 Connect the HI coaxial leads to the two capacitors and null the bridge with the CAPACITANCE and CONDUCTANCE dials. Record the readings. Reverse the two LO coaxial lead connections, and again null and read.

5.5.3 INTERPRETING READINGS

5.5.3.1 Ideally the two capacitance readings would be in opposite directions from the set-up reading, and by equal amounts. However, due to minor lead unbalances the usual result will be two readings that are not symmetrically offset from the set-up point, and which may both be in the same direction from it. In any case, one half of the difference between readings is the amount by which the two capacitors differ.

5.5.3.2 Also the difference readings are always direct sensing in that the connection giving the higher reading is the one where the capacitor connected to the TEST receptacles is larger than that on the STANDARD ARM receptacles. It is worthwhile noting that one of the main advantages of using this method of measuring capacitance differences is that the effects of zero shift in the bridge are eliminated.

5.5.3.3 As a word of caution, this method is most useful for determining very small differences (such as T.C. effects) between rather large capacitors - roughly between 10 and 1000 pf. It can give serious errors when very large and unequal stray capacitances exist from either side of the test of reference capacitor to ground.

6.0 MEASURING WITHOUT LIMIT FUNCTION

6.1 OPERATION

6.1.1 Complete connection to the test, utilizing appropriate techniques as described in Section 5 and Zero Balance as described in Section 4.

6.1.2 Adjust the CAPACITANCE and CONDUCTANCE dials for best null indication on the meter. The null should occur between 100 and 1000 on both the CAPACITANCE and CONDUCTANCE dials. If it occurs above or below these values, the next indicated MULTIPLY C and/or DIVIDE G/MULTIPLY R range should be used.

Note:

Whenever the capacitance or conductance ranges are changed the bridge must be zero balanced as detailed in paragraph 4 before measuring.

6.2 INTERPRETING READINGS

6.2.1 After balancing both capacitance and conductance to a satisfactory degree of precision, the capacitance of the test specimen is determined directly from the CAPACITANCE dial reading, multiplying by the decimal factor indicated on the MULTIPLY C knob.

6.2.2 The conductance of the test specimen is found by dividing the reading indicated on the G scale of the conductance dial by the factor indicated on the DIVIDE G/MULTIPLY R dial.*

*For corrections applying only to measurements made on the XI MULTIPLY CAPACITANCE range and with the test connected directly to the binding posts or coaxial receptacles - see Figure #1.

6.0 MEASURING WITHOUT LIMIT FUNCTION

6.1 OPERATION

6.1.1 Complete connection to the test, utilizing appropriate techniques as described in Section 5 and Zero Balance as described in Section 4.

6.1.2 Adjust the CAPACITANCE and CONDUCTANCE dials for best null indication on the meter. The null should occur between 100 and 1000 on both the CAPACITANCE and CONDUCTANCE dials. If it occurs above or below these values, the next indicated MULTIPLY C and/or DIVIDE G/MULTIPLY R range should be used.

Note:

Whenever the capacitance or conductance ranges are changed the bridge must be zero balanced as detailed in paragraph 4 before measuring.

6.2 INTERPRETING READINGS

6.2.1 After balancing both capacitance and conductance to a satisfactory degree of precision, the capacitance of the test specimen is determined directly from the CAPACITANCE dial reading, multiplying by the decimal factor indicated on the MULTIPLY C knob.

6.2.2 The conductance of the test specimen is found by dividing the reading indicated on the G scale of the conductance dial by the factor indicated on the DIVIDE G/MULTIPLY R dial.*

*For corrections applying only to measurements made on the XI MULTIPLY CAPACITANCE range and with the test connected directly to the binding posts or coaxial receptacles - see Figure #1.

6.2.3 Except on the XI Capacitance range, the equivalent shunt resistance is determined by multiplying the reading indicated on the R scale by the factor shown on the DIVIDE G/MULTIPLY R dial. On the XI capacitance range the most accurate procedure is to determine the conductance, then take the reciprocal of it to obtain the equivalent shunt resistance. For example, suppose that when using the X1000 DIVIDE G/MULTIPLY R range a CONDUCTANCE dial reading of 40 was observed for a 200 pf mica capacitor. This is, of course, +0.04 μmho. A look at Figure #1 shows that the conductance correction for a 200 pf capacitor should be -.02 μmho. Subtracting this from the measured value gives +.02 μmho as the corrected conductance. The reciprocal of this would be 50. megohms (.02 x 10^{-6} μmhos). To avoid division, the CONDUCTANCE dial may be convenient to use for conversion from μmhos to ohms. In the above example, the dial readings for the corrected conductance .02 corresponds to 50 K on the resistance scale. Multiplying the resistance reading by 1000 (X1000 range) gives the correct figure of 50,000,000 or 50. megohms.

$$\left(R + \frac{1 \times 10^6}{G}\right. \quad \text{where G is in micromhos)}$$

6.2.4 The Q and Dissipation Factor, D, of the test sample may be computed from the following formulae:

$$A = \frac{2\pi fC}{G} = \frac{WC}{G} \qquad D = \frac{1}{Q}$$

Therefore at 1 Mc: $Q = 6.28 \frac{C}{G}$

Where C = test specimen capacitance in pf.
" G = test specimen conductance in micromhos.
" f = frequency in megacycles.

6.3 MEASUREMENT OF RESISTOR CAPACITANCE

6.3.1 To accurately measure the capacitance of resistors (those with equivalent parallel resistance in the general region between 1000 Ω to ∞) it is necessary to construct and use a set of correction curves for each individual bridge.

6.3.2 To do this, a set of deposited carbon resistors are required (Mepco 1/4 W Type C10 is recommended) with values ranging between 1000 Ω and 1 megohm. Measure each of the resistors on the bridge and plot the capacitance readings, preferably on semi-log graph paper. Use the TRUE capacitance reading (0.07 pf for Mepco 1/4 W Type C10) as the zero reference for determining the magnitude and direction of the bridge error. Typical data is shown in the following table; however, do not use data unless it is verified by test.

*Connect by pushing their leads (cut to approximately 3/4 inch long on each end) into the centers of the HI and LO coaxial TEST receptacles of the bridge.

	Resistor (Ω)	Bridge Reading (1)	True Value (2)	Indicated Correction (1) - (2) with sign inverted
	1 K	-0.33 pf	+0.07 pf	+0.40 pf
XI	1.2 K	0.00	"	+0.07
DIVIDE G/	1.5 K	+0.11	"	-0.04
MULTIPLY R	2 K	+0.26	"	-0.19
range	3 K	+0.22	"	-0.15
	5 K	+0.20	"	-0.13
	10 K	+0.10	"	-0.03
	10 K	+0.35 pf	+0.07 pf	-0.28 pf
X10	12 K	+0.39	"	-0.32
DIVIDE G/	15 K	+0.35	"	-0.28
MULTIPLY R	20 K	+0.30	"	-0.23
range	30 K	+0.22	"	-0.15
	50 K	+0.14	"	-0.07
	100 K	+0.10	"	-0.03
	100 K	+0.088 pf	+0.07 pf	-0.018 pf
X100	120 K	+0.091	"	-0.021
DIVIDE G/	150 K	+0.085	"	-0.015
MULTIPLY R	200 K	+0.078	"	-0.008
range	300 K	+0.068	"	-0.002
	500 K	+0.064	"	+0.006
	1 Meg	+0.07	"	0.00

Capacitance Correction Factor For Resistor

6.3.3 Note that the capacitance error does not depend on the capacitance value of the test, but on its resistive component. Hence for any given value of equivalent resistance it is what might be called a "fixed pf" error, the effect on the test varying in percentage with the size of the test capacitance.

6.3.4 For example, if the test consisted of a capacitor with equivalent parallel resistance of 5000 ohms and a true capacitance of .5 pf (such as might be found in semiconductor work) the measured C would be about .63 pf. If the error is not corrected, this would represent a deviation of about 25% from the true value. If the true capacitance had been 5 pf however, the error would have been only about 2.5%.

7.0 MAINTENANCE

7.1 GENERAL

7.1.1 The Capacitance Limit Bridge has been carefully calibrated at the factory with three-terminal capacitance standards certified by the National Bureau of Standards. Unless comparable standards are used, recalibration of this instrument should be performed only by the manufacturer. Boonton Electronics Capacitance Standards are available should the customer choose to attempt recalibration.

7.2 REMOVING FROM THE CABINET

7.2.1 Remove the screws holding the FRONT PANEL to the cabinet. Grasp the upright handles and slide the instrument out of the cabinet.

7.3 PERFORMANCE CHECKS

7.3.1 GENERAL

7.3.1.1 The series of tests to follow require no auxiliary equipment and are designed to detect any faulty instrument operation. However, an instrument that passes these tests is not a guarantee of a normal instrument.

7.3.2 TESTS

7.3.2.1 Dial Stops: Rotate the CAPACITANCE dial to the left of zero until a stop is reached at -50 pt. The fiducial should be over the red 50 mark on the inner part of the vernier dial and coincide with the black 0±2 small division on the outer part of the vernier dial. Turn to the upper stop which should be approximately 1050±5 major divisions.

7.3.2.2 Capacitance Backlash: Zero balance instrument on 1 MULT C range. Turn the CAPACITANCE dial from at least 10 dial divisions off null into null. The point of null should occur at the same at essentially 0±1 small division whether approached from c.w. or c.c.w. direction. However, if the backlash is greater than 1 small division, the instrument is still usable provided the null is always approached from the same direction.

7.3.2.3 Capacitance Zero: Set the instrument to the .001 MULT. C. and 1000 DIVIDE G/MULT R positions. After carefully zero balancing the instrument, switch to progressively high MULT. C. ranges. In each range restore balance with the CAPACITANCE dial only, observing that in all cases not more than ±4 major divisions are required.

7.3.2.4 Conductance Zero: Set the MULT. C. and DIVIDE G/MULT R switches to 1000 and the R/C zero control to 12 o'clock. Zero balance the instrument with the main CONDUCTANCE dial only and capacitance controls. The conductance null should occur within 2 minor G division each time the R/G range switch is set to a higher range. If the R/G ZERO control is required it should not move more than ±1/2 hour past 12 o'clock.

7.3.2.5 Sensitivity: Set the MULT. C. to .001, the DIVIDE G/MULT R switch to 10, TEST LEVEL ADJ max. and zero balance the instrument. Rotate the CAPACITANCE dial ±2 divisions above and below zero and note that the LAMPS change state. Rotate the CAPACITANCE dial to 10 divisions above zero. Observe that 10 μa are reading on the NULL METER.

7.3.2.6 Limit Operation: Set the MULT. C. to .01, TEST LEVEL ADJ to max., DIVIDE G/MULT R switch to 10 and zero balance the instrument. Set up for limit operation as described in section 4.1 but return the CONDUCTANCE dial to the last red graduation. (Insure that the capacitance still is at Opf by rocking the capacitance dial and observing lamps blinking.) Rotate the CONDUCTANCE dial to the middle of the red graduation, and then rock the CAPACITANCE dial to find the point where the lamps alternately blink. The lamp blinking point should not move by more than ±2 major dial divisions to the left or right Opf null.

8.0 SHIPPING INSTRUCTIONS

8.1 METHOD

8.1.1 If it becomes necessary to ship the instrument for any reason, wrap the unit with heavy wrapping paper and seal the seams with gummed tape. Place the instrument into a fibreboard carton large enough to allow at least three inches of soft packing material to be placed between the instrument and the sides of the box.

9.0 WARRANTY

9.1 GUARANTEE

9.1.1 BOONTON ELECTRONICS CORPORATION guarantees to the original purchaser that each instrument it manufactures is free from defects in material and workmanship for a period of one year after date of initial shipment. Our liability is limited to repairing or replacing any defective part with the exception of vacuum tubes, panel lamps, fuses, and batteries. The warranty lapses if, upon our examination, we judge that the instrument has been abused in any way.

9.2 PROCEDURE TO FOLLOW WHEN INSTRUMENT IS DEFECTIVE

9.2.1 Call our plant or our representative nearest you. A simple solution may result from discussion of the problem with our trained personnel.

9.2.2 If the fault is not readily eliminated, prepare the instrument for return to us. Pack carefully in a sturdy container using several inches of shock absorbing material on all six sides of the instrument. Include all probes, cables or accessory units. On all paper work pertaining to the returned instrument, note the model and serial number and state briefly the details of the fault. Ship to us transportation charges prepaid.

9.2.3 If the instrument is within the warranty, we will repair and return to you transportation charges prepaid. If the instrument is beyond the one year warranty period, we will repair and return it unless approval on a cost estimate is requested. If the instrument is within the one year warranty period, but our examination reveals abuse, we will await approval of our cost estimate before proceeding with repairs.

TABLE OF REPLACEABLE PARTS
FOR 77A

NOTE: Components in the "bridge" unit have not been included since, in general, their replacement must be followed by adjustments that require specialized equipment and techniques.

- CAPACITORS -

Ref.No.		Description		BEC Part No.
C101	Durmica	240pf ±5% 500V	Arco DM-15	200 506
C102	Durmica	150pf ±5%	Arco DM	200 032
C103	Durmica	20pf ±5% 200V	Arco DM-10	200 027
C104	Mylar	0.1µf ±20% 200V	Sprague	230 116
C105	Var. Air	2-10pf	Hammerlund MAC-10	275 135
C106	Mylar	0.1µf ±20% 200V	Sprague	230 116
C107	Durmica	120pf ±5% 500V	Arco DM-15	200 002
C108	Mylar	0.0033µf 200V	Sprague	230 119
C109	Mylar	0.1µf ±20% 200V	Sprague	230 116
C110	Durmica	120pf ±5% 500V	Arco DM-15	200 002
C111	Mylar	0.1µf ±20% 200V	Sprague	230 116
C112	Var. Ceramic	4.5-25pf	Erie NPO TS2A	281 000
C113	Tubular	36pf ±5%	Erie 301-651-U2	220 117
C114	Tubular	36pf ±5%	Erie 301-651-U2	220 117
C115	Durmica	330pf ±1% 500V	Arco DM-15-331	200 033
C116	Durmica	330pf ±1% 500V	Arco DM-15-331	200 033
C117	Durmica	10pf ±5%	Arco DM-	200 022
C118	Durmica	120pf ±5% 500V	Arco DM-15	200 002
C119	Durmica	120pf ±5% 500V	Arco DM-15	200 002
C120	Durmica	120pf ±5% 500V	Arco DM-15	200 002
C121	Mylar	0.1µf ±20% 200V	Sprague	230 116
C122	Var. Piston	0.7-3pf	Erie Poly Trimmer	279 109
C123	Var. Piston	0.7-3pf	Erie Poly Trimmer	279 109
C124	Durmica	120pf ±5% 500V	Arco DM-15	200 002
C125	Durmica	120pf ±5% 500V	Arco DM-15	200 002

Ref. No.		Description			BEC Part No.
C126	Durmica	120pf ±5%	500V	Arco DM-15	200 002
C127	Mylar	0.1µf ±20%	200V	Sprague	230 116
C128					
C129	Durmica	0.015µf		Arco DM-	203 009
C130	Durmica	120pf ±5%	500V	Arco DM-15	200 002
C131	Mylar	0.1µf ±20%	200V	Sprague	230 116
C132	Mylar	0.0033µf ±	200V	Sprague	230 119
C133	Mylar	0.0033µf ±	200V	Sprague	230 119
C201	Electrolytic	20-20µf	450V	Mallory FP-234	283 100
C301	Var. Air	50pf		Hammerlund MAPC 50	275 103
C302	Mylar	0.05µf ±20%	400V	Cornell Dubilier PM4S5	234 002
C304	Var. Air	0.5-30pf		Johanson	279 103
C305	Var. Air	0.5-30pf		Johanson	279 103
C306	Var. Air	3-8pf		Johanson #1802	279 108
C307	Sil. Mica	100pf		Sangamo	201 124
C308	Var. Air	3-8pf		Johanson #1802	279 108
C310	Mylar	0.15µf	100V	Cornell Dubilier	234 038
C311	Paper	0.5µf	400V	Aerovox	230 118
C312	Var. Ceramic	4.5-25pf		Erie NPO TS2A	281 000
C313	Var. Piston	0.7-3pf		Erie Poly Trimmer	279 109
C314	Var. Air	10-10pf		Jackson Bros. C-808	275 129

NOTE: Above voltage ratings are working volts

- RESISTORS -

Ref. No.		Description			BEC Part No.
R101	Comp.	200K ±5%	1/2 watt	AB Type EB	301 142
R102	Comp.	470Ω ±5%	1/2 watt	AB Type EB	301 079
R103	Comp.	22K ±5%	1/2 watt	AB Type EB	301 119
R104	Comp.	100Ω ±5%	1/2 watt	AB Type EB	301 063
R105	Comp.	200K ±5%	1/2 watt	AB Type EB	301 142

Ref. No.		Description			BEC Part No.
R106	Comp.	1M ±5%	1/2 watt	AB Type EB	301 159
R107	Comp.	2.2K ±5%	1/2 watt	AB Type EB	301 095
R108	Comp.	470Ω ±5%	1/2 watt	AB Type EB	301 079
R109	Comp.	22K ±5%	1/2 watt	AB Type EB	301 119
R110	Comp.	100Ω ±5%	1/2 watt	AB Type EB	301 063
R111	Comp.	200K ±5%	1/2 watt	AB Type EB	301 142
R113	Comp.	2.2K ±5%	1/2 watt	AB Type EB	301 095
R114	Comp.	100Ω ±5%	1/2 watt	AB Type EB	301 063
R115	Comp.	1M ±5%	1/2 watt	AB Type EB	301 159
R116	Comp.	1M ±5%	1/2 watt	AB Type EB	301 159
R117	Comp.	1M ±5%	1/2 watt	AB Type EB	301 159
R118	Comp.	560K ±5%	1/2 watt	AB Type EB	301 153
R119	Comp.	560K ±5%	1/2 watt	AB Type EB	301 153
R120	Comp.	10K ±5%	1/2 watt	AB Type EB	301 111
R121	Comp.	2.7M ±5%	1/2 watt	AB Type EB	301 169
R122	Comp.	560K ±5%	1/2 watt	AB Type EB	301 153
R123	Comp.	2.2K ±5%	1/2 watt	AB Type EB	301 095
R124	Comp.	100Ω ±5%	1/2 watt	AB Type EB	301 063
R125	Comp.	309K ±1%	1/2 watt	AB Type EB	306 537
R126	Var.	100K Trimpot ±20%		Bourns #30685-1-104 6406A	311 182
R127	Comp.	51K ±5%	1/2 watt	AB Type EB	301 128
R128	Comp.	309K ±1%	1/2 watt	AB Type EB	306 537
R129	Comp.	470Ω ±5%	1/2 watt	AB Type EB	301 079
R130	Comp.	51K ±5%	1/2 watt	AB Type EB	301 128
R131	Comp.	470Ω ±5%	1/2 watt	AB Type EB	301 079
R132	Comp.	22Ω ±5%	1/2 watt	AB Type EB	301 047
R133	Comp.	22Ω ±5%	1/2 watt	AB Type EB	301 047
R201	Comp.	1M ±20%	1 watt	AB Type GB	302 128
R202	Wire Wound	5K ±5%	10 watt		312 101
R301	Comp.	675Ω ±1%	1/2 watt		306 625
R302	Var.	2K Trimpot		Bourns 200L-1-202 6420AA	311 203

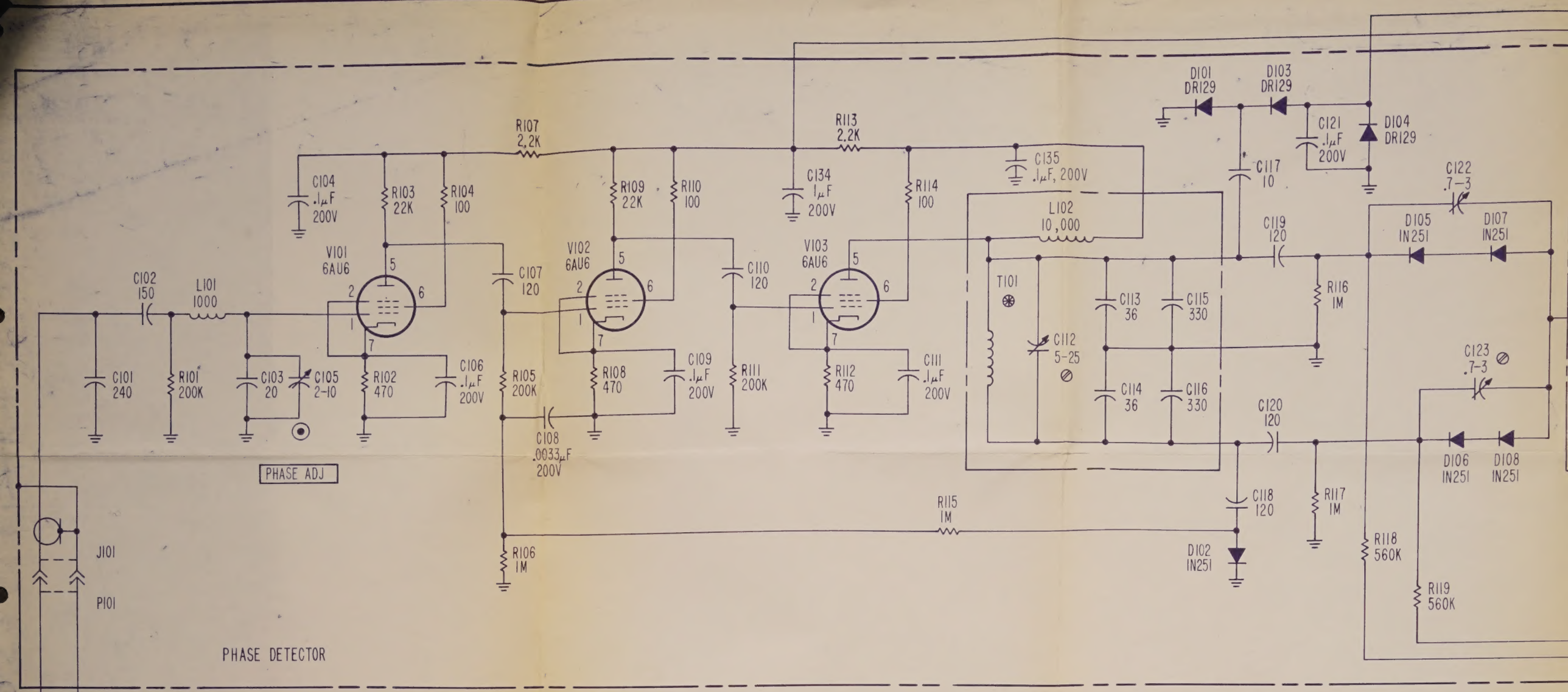
Ref. No.		Description			BEC Part No.
R303	Dep. Car.	49.9K ±1%	1/4 watt	MEPCO C-10	305 442
R304	Comp.	15Ω ±5%	1/2 watt	AB Type EB	301 043
R305	Dep. Car	301Ω ±1%	1/4 watt	MEPCO C-10	305 177
R306	Dep. Car	4.75K ±1%	1/4 watt	MEPCO C-10	305 321
R307	Dep. Car	499K ±1%	1/4 watt	MEPCO C-10	305 562
R308	Dep. Car	200Ω ±1%	1/4 watt	MEPCO C-10	305 156
R310	Var.	5K ±10%	2 watt	AB JA1N048PS028A	311 202
R311	Dep. Car	422Ω ±1%	1/4 watt	MEPCO C-10	305 194
R312	Dep. Car	499K ±1%	1/4 watt	MEPCO C-10	305 562
R313	Var.	10K ±10%	2 watt	AB Type J	311 124
R401	Var.	50K ±10%	2 watt	AB Type J	311 129
R402	Comp.	24K ±5%	2 watt	AB Type HB	303 634
D101	Diode	DR-129	Germanium	General Instrument	530 010
D102	Diode	1H251	Silicon	Texas Instrument	530 043
D103	Diode	DR-129	Germanium	General Instrument	530 010
D104	Diode	DR-129	Germanium	General Instrument	530 010
D105	Diode	IN251	Silicon	Texas Instrument	530 043
D106	Diode	1N251	Silicon	Texas Instrument	530 043
D107	Diode	1N251	Silicon	Texas Instrument	530 043
D108	Diode	1N251	Silicon	Texas Instrument	530 043
D109	Diode	1N251	Silicon	Texas Instrument	530 043
D110	Diode	1N251	Silicon	Texas Instrument	530 043
D111	Diode	1N251	Silicon	Texas Instrument	530 043
D201	Diode	UZ-806	Zener	Unitrode	530 041
F101	Fuse	1.2A 125V		Fusetron	545 509
L101	Choke, RF	1000μh ±5%		Essex	400 095
L102	Choke, RF	10,000μh ±5%		Essex	400 101
L103	Choke, RF	10,000μh ±5%		Essex	400 101

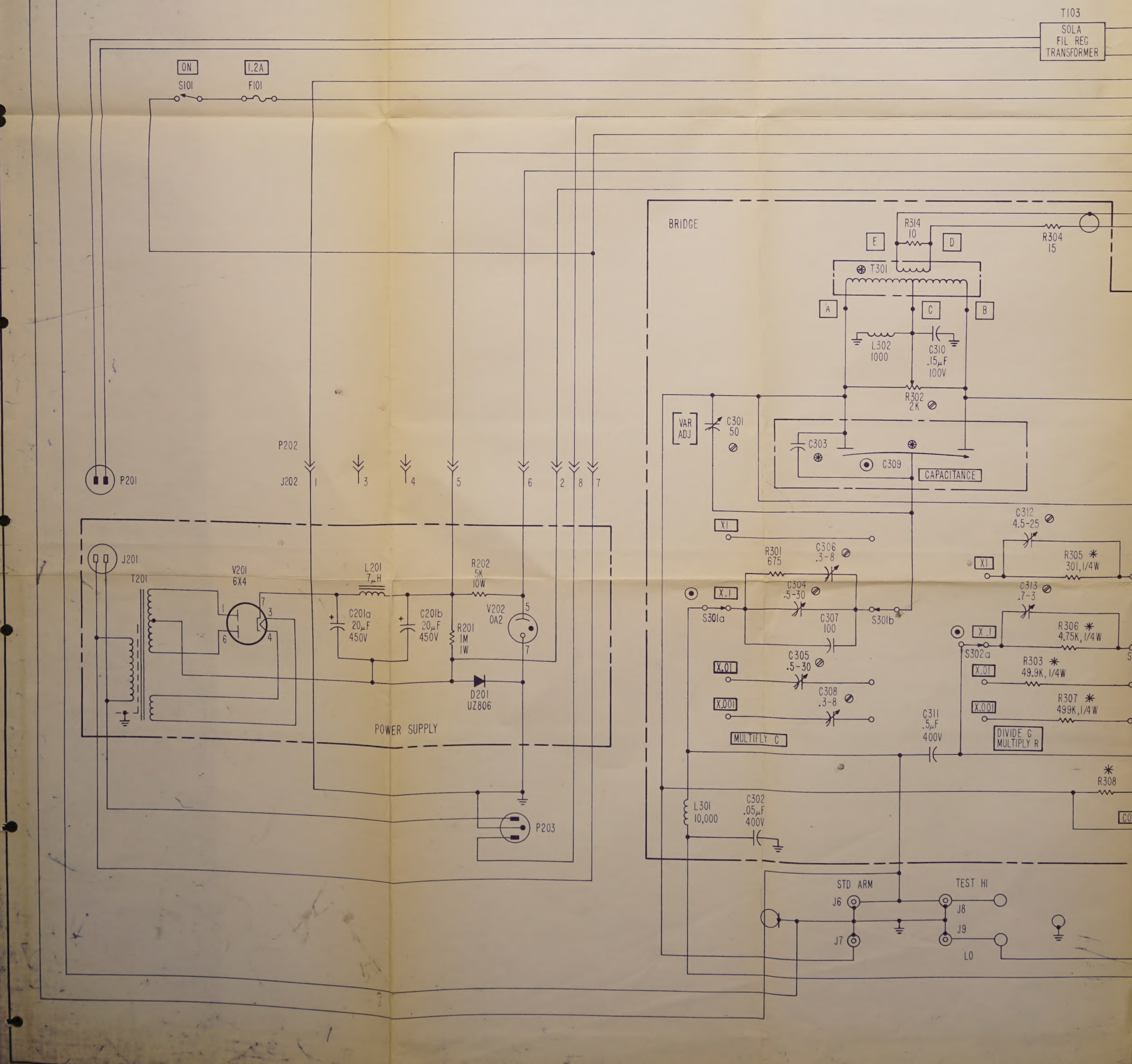
Ref. No.		Description		BEC Part No.
L201	Choke, Power	7hy 500Ω 50ma	Stancor C-1707	440 001
L301	Choke, RF	10,000μh ±5%	Essex	400 101
L302	Choke, RF	1000μh ±5%	Essex	400 095
I101	Light	Pilot	Dialco #81410-11	474 100
I102	Light	Limit	Dialco #101-5030-971	474 109
I103	Light	Limit	Dialco #101-5030-972	474 110
K101	Coil	Solenoid	Coto Coil Co. UD-24P	470 501
K102	Coil	Solenoid	Coto Coil Co. UD-24P	470 501
M101	Meter Taut Band	50μa Scale	Weston #1921T	554 140
S101	Switch	Toggle SPST	Carling 110-63	465 105
S301	Switch	2P4P	CRL	466 129
S302	Switch		CRL PA279-1194	466 108
S401	Switch	Non-Shorting DP4T	CRL PA-2003	466 147
T101	Trans.	Special		410 007
T102	Trans.	Special		410 014
T103	Trans.	6.3V 2.38A	Sola Type CV-S	446 024
T201	Transformer, Power		Stancor #1377	446 007
T301	Transformer, Bridge Input	Special		
V101	Tube	6AU6		526 6AU6
V102	Tube	6AU6		526 6AU6
V103	Tube	6AU6		526 6AU6
V104	Tube	6AU6		526 6AU6
V105	Tube	12AT7		526 12AT7
V106	Tube	12AT7		526 12AT7
V201	Tube	6X4		526 6X4
V202	Tube	OA2		526 OA2
XTAL 101	Osc. Crystal	1mc	Jam Knight CR 18/U	547 015

Warranty

Boonton Electronics Corporation warrants its products to the original Purchaser to be free from defects in material and workmanship and to operate within applicable specifications for a period of one year from date of shipment, provided they are used under normal operating conditions. This warranty does not apply to vacuum tubes that have given normal service, to sealed assemblies which have been opened, or to any item which has been repaired or altered without our authorization.

We will repair or, at our option, replace at no charge any of our products which are found to be defective under the terms of this warranty.


R107 2.2K
R113 2.2K
C104 .1μF 200V
R103 22K
R104 100
C134 1μF 200V
R114 100
C135 .1μF, 200V
D101 DR129
D103 DR129
C121 .1μF 200V
D104 DR129
C117 10
C122 .7-3
L102 10,000
C119 120
D105 IN251
D107 IN251
V101 6AU6
V102 6AU6
V103 6AU6
C102 150
L101 1000
C107 120
R109 22K
R110 100
C110 120
T101
C113 36
C115 330
R116 1M
C101 240
R101 200K
C103 20
C105 2-10
R102 470
C106 .1μF 200V
R105 200K
R108 470
C109 .1μF 200V
R111 200K
C112 5-25
R112 470
C111 .1μF 200V
C114 36
C116 330
C123 .7-3
C108 .0033μF 200V
C120 120
D106 IN251
D108 IN251
PHASE ADJ
R115 1M
C118 120
R117 1M
D102 IN251
R118 560K
R119 560K
J101
P101
PHASE DETECTOR


T103
SOLA FIL REG TRANSFORMER
ON
S101
1.2A
F101
BRIDGE
R314 10
E
D
R304 15
T301
A
C
B
L302 1000
C310 .15μF 100V
R302 2K
VAR ADJ
C301 50
C303
C309
CAPACITANCE
X1
R301 675
C306 .3-8
C304 .5-30
C307 100
S301a
S301b
X.1
X.01
X.001
C305 .5-30
C308 .3-8
MULTIFLY C
C311 .5μF 400V
C312 4.5-25
R305 ✱ 301, 1/4W
C313 .7-3
R306 ✱ 4.75K, 1/4W
S302a
R303 ✱ 49.9K, 1/4W
R307 ✱ 499K, 1/4W
DIVIDE G MULTIPLY R
R308
L301 10,000
C302 .05μF 400V
STD ARM
TEST HI
J6
J7
J8
J9
LO
P201
J202
P202
1
3
4
5
6
2
8
7
J201
T201
V201 6X4
L201 7μH
C201a 20μF 450V
C201b 20μF 450V
R202 5K 10W
R201 1M 1W
V202 0A2
D201 UZ806
P203
POWER SUPPLY

INDICATOR

R120 10K
R121 2.7M
L103 10,000
C125 120
C127 .1μF 200V
C126 120
C128 50-500
C124 120
C130 120
D111 IN251
D110 IN251
R122 560K
D109 IN251
C131 .1μF 200V
R123 2.2K
R124 100
V104 6AU6
V105 12AT7
XTAL101 1MC
C129 .015μF
J102
P102
R126 100K
R125 309K
R128 309K
R129 470
R127 51K
V106 12AT7
R130 51K
R131 470
R132 22
K101
K102
R133 22
C132 .0033μF 200V
C133 .0033μF 200V
V101 V102 V103 V104 V105 V106
J103 PLUG SIDE
P104
J104
I101
R310 5K 2W
TEST LEVEL ADJ
I102
I103
M101

CURRENT
J401
R401 50K
S401a
R402 24K 2W
ADJUST
INTERNAL BIAS MONITOR
+INT
S401b
OFF
-INT
EXT
EXTERNAL BIAS
400 VOLTS AT 100 MC
BIAS

C ZERO
C114 10-10
R312 499K 1/4W
R311
R309
R313 10K 2W
R/G ZERO

NOTES:
RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.

⏚ GROUNDS

◉ FRONT PANEL CONTROL

▭ EXTERNAL MARKINGS

⊏⊐ INTERNAL MARKINGS

⊘ CALIBRATION CONTROL

⊛ FACTORY SELECTED VALUE

✳ PRECISION RESISTORS

CAPACITANCE IN PICOFARADS UNLESS OTHERWISE SPECIFIED.

ALL RF CHOKES IN MICRO HENRIES UNLESS OTHERWISE SPECIFIED.

LAST NUMBER USED:
R133 C135
R202 C201b
R314 C314
R402

ISSUE NO.	CHANGE

SCALE:		
DRN		11-20-64
CKD	J.F.D.	12-2-64
APP	S.B.	12-3-64

FIRST USED ON: 77A

SCHEMATIC

E 830206 A

MP MASTER
MA25115